If Bill Phillips were Governor ...?

Some implications of his work for contemporary macroeconomic policy

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If Bill Phillips were Governor ...?
Some implications of his work for contemporary macroeconomic policy

Grant M. Scobie*

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> *"Having looked at monetary policy from both sides now, I can testify that central banking in practice is as much art as science. Nonetheless, while practicing this dark art, I have always found the science quite useful."*
>
> Alan S. Blinder[1]

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[1] Blinder (1997), p. 17.

1. Introduction

There would hardly be a student of economics most anywhere who had not heard the name Phillips. That name is immortalised in the so-called "Phillips Curve." Equally remarkable, is that probably less than one percent of those familiar with this diagram would have the slightest idea that A.W.H. Phillips was a New Zealander.

But we can but be grateful to another New Zealander, former Governor ***Alan Bollard.*** Alan has been a long-standing student of Phillips, and his latest work is ***A Few Hares to Chase: The Economic Life and Times of Bill Phillips***[2] As the subtitle suggests, the book is in two parts. the first covers the extraordinary life of Phillips from his growing up in the rural village of Te Rehunga near Dannevirke[3], through his travels to Russia and China, and to the horror of his time in a Japanese PoW camp when captured in Singapore while serving with the RAF in WWII. The second part is a synthesis of the substantial contributions Phillips made as an economist at the London School of Economics and Political Science (LSE).

His career at LSE was truly remarkable. His initial training was as an electrical engineer; after the war he barely scraped through a degree in sociology. But such was his subsequent work that within a few years of finishing that mediocre undergraduate degree in sociology, he was a reader, and subsequently a full professor of economics in a named chair at the LSE! Not the least of his accomplishments was the design and construction of a hydraulic machine which essentially solved a set of differential equations to describe the dynamic path of an economy in response to policy changes. For those readers, not familiar with the machine, an example is now (thanks in large part to Alan Bollard) on permanent display in the Reserve Bank of New Zealand Museum, at 2 The Terrace in Wellington. It is one of the few operational versions still in existence.[4]

This essay is not however, a review of Bollard's book. That has been ably done by Nicolas Barr (2016). Having said that, the book provides an admirable synthesis of much of Phillips's research work. Rather the purpose of this essay is to address the question: "Are there elements of Phillip's work that are still relevant today for macroeconomic policy making today?"

In undertaking this task, I will draw on the summary of his work from the second part of Bollard's book. But I will also cast the net a little wider to draw on the writings of others who have reviewed and built on the work of Phillips; and naturally I will call on a number of the

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[2] For those who might be wondering about the source and meaning of the title, it is from a comment made by Phillips when, on his 60th birthday, colleagues presented him with the draft of a book in his honour. With characteristic humility, he observed: "I did not do very much. I just put out a few hares for other people to chase."

[3] The author has an extremely modest (tenuous?) connection to Phillips - we are both alumni of Dannevirke High School and we lived about 0.5 km from each other in adjacent suburbs (Curtin and Lyons) in the Woden Valley of Canberra in the 1960s .

[4] See Section 2.1 for a discussion of the machine. Details of the machine to the Phillips machine at the Reserve Bank can be found at:
https://www.rbnz.govt.nz/research-and-publications/videos/making-money-flow-the-moniac
A further machine is on display in the British Science Museum in London located, incidentally, in the same room as the Babbage Accounting machine:
https://collection.sciencemuseumgroup.org.uk/objects/co64127/phillips-economic-computer-analog-computer
https://www.sciencemuseum.org.uk/objects-and-stories/how-does-economy-work

original papers by Phillips. However, any suggestion that I will fully capture all that has been written about Phillips, his life and work, must be summarily dismissed. Put "AWH Phillips economist" into Google search and one gets 201,100 links; for "Phillips curve" a mere 717,000.

The essay proceeds as follows. Phillips' work is grouped into four broad areas:

- Inflation and Unemployment
- Dynamic Stabilisation and Optimal Control
- Economic growth
- Econometrics

This is followed by a brief discussion of forecasting and policy models with a sketch of their use in selected countries. A concluding section follows.

In addition to the four areas listed above, Phillips undertook research on China; in fact his appointment to the Australian National University in 1967 was on the condition that he would work on economics for three days a week, while on the other two he would focus his research on China.[5] Why did Phillips switch his attention to China? He had maintained a longstanding interest in China, and had travelled there as part of his pre-war wanderings in Asia. Furthermore, he had acquired a command of the language while in a PoW camp. But above all, he had become somewhat disillusioned with the sometimes almost acrimonious debate between different schools of macroeconomic policy "which he found profoundly distasteful and depressing, and gradually abandoned macroeconomics for Chinese economic studies" (Lesson, 1997).

However, I have opted not to address this latter element of Phillip's work as arguably it does not have quite the same direct relevance to macro economic policy. Rather, it was an extension to China of his earlier work on stabilisation and growth for developed economies, with the additional challenge that at the time the Chinese economy lacked markets which would have generated wage and price data. And sadly, his work on China was cut short by a debilitating stroke.

It should be stressed at the outset that the four areas listed above are but a very crude taxonomy of Phillips' work. As will become apparent, it is difficult (perhaps impossible) at times to sustain any significant degree of separation between the areas. And arguably there will be times when it is less than optimal to try and achieve such separation. It is probable Phillips himself would not have viewed his work as falling into neat boxes. In fact, the very evolution of his work involves moving from models of wages and employment, to models for evaluating stabilisation policies and estimating their parameters, and finally incorporating those elements in models of growth.

In each section, devoted to one of these areas, I first identify the principal contributions made by Phillips. I then endeavour to trace any links between those contributions and today's approach to economic policy. Clearly, much of Phillips's work was rightly cast within the context of his times. So to this extent, we might expect that given we are in a very different world today, that at least some of his insights would be less relevant than others. That is undoubtedly true. Phillips, for example, did not concern himself with the simultaneous occurrence of low inflation and low unemployment, or the operation of monetary policy when interest rates are very low or even negative. Despite this we shall see that there are important strands of his work that arguably underpin some of today's approaches to economic policy.

[5] For a detailed history of Phillip's appointment and time at the ANU together with an earlier visit to Melbourne and Sydney, see Cornish and Millmow (2016).

However, it is pertinent to keep in mind, as is the case almost the universally, that innovations are built on the work of predecessors. And in a number of key areas, we shall see that Phillips drew on existing economic models. However it is notable that in key papers he published (eg 1954, 1957, 1961a and b) there are remarkably few references to earlier economists (in contrast to more numerous citations to work on mathematics, engineering and control systems). In part that might simply reflect the fact that he did not enjoy the wide, low cost access to the literature that the internet provides todays' researchers. Notwithstanding, his genius was to make far reaching advances to the extant stock of knowledge.

In assessing the legacy of Phillips, it will be important to distinguish two channels. In the first place, there is a vast stream of economic modelling which draws on Phillips's contributions. There would scarcely be a single scholarly paper on inflation and unemployment for example, that did not include an acknowledgement to Phillips. The second channel, and one most closely allied to the aims of this essay, is the more direct influence on policy decisions. Naturally this latter influence could come about as a result of incorporating Phillips's ideas in economic modelling (the first channel) which in turn then directly underpins some aspect of policy making. The distinction between the two channels reflects the fact that there is a plethora of academic papers with elaborate models having a greater or lesser connection to Phillips, but which arguably made a greater contribution to their author's CV than to applied policy making.

2. Inflation and Unemployment[6]

In commenting on a paper by Dicks-Mireaux and Dow (1959), Phillips opined that "One of the important problems of our time is that of maintaining a high level of economic activity and employment while avoiding a continual rise in prices" (1959, p.176). This concern had clearly underpinned much of Phillip's early work.

2.1 The Phillips Machine[7]

No discussion of Phillips' work can overlook the role of the *Monetary National Income Analogue Computer* (MONIAC). In one of his earliest papers documenting the machine, Phillips wrote:

> "Fundamentally, the problem is to design and build a machine the operations of which can be described by a particular system of equations which it may be found useful to set up as the hypotheses of a mathematical model, in other words a calculating machine for solving differential equations" (Phillips, 1950, p.283).

Strictly a more accurate title would be the Phillips/Newlyn Machine, reflecting the close collaboration in the machine's development that Phillips had with Walter Newlyn. The opening sentence of a paper by Newlyn (1950) reads:

> "The model shown in the photo opposite was designed and constructed by Mr A.W. Phillips, in collaboration with the writer, in connection with the teaching of monetary theory" (p.110).

[6] Smith and Aziz (2019) provide a concise summary of the theory and empirical developmenets on inflation and unemployment since the 1950s.

[7] For the background and a detailed description of the MONIAC machine see Newlyn (2000); Vines (2000); Barr (2000); Dorrance (2000); Goodwin (2000); Swade (2000); and Ng and Wright (2007).

It is important however in the context of this essay to underscore the fact the Phillips himself viewed as pedagogical, the primary purpose of his hydraulic construction. For example, Colander (2011) argues that …"He did not mean it to be used by policy makers, nor did he mean it to be used to advance scientific knowledge" (p.2). Having developed the machine, Phillips was required by the LSE to document the theoretical underpinnings of his model. In doing so he wrote:

> "…machines are intended for exposition" and are "an attempt to develop some mechanical models which may help non-mathematicians by enabling them to see the quantitative changes that occur in an inter-related system of variables following initial changes in one or more of them." (Phillips, 1950, p. 283).

Colander (2011) stresses that inherent limitations of the machine restricted its usefulness for generating policy recommendations, while such limitations did not preclude its use as a pedagogical aid. A key shortcoming in terms of policy formulation was the machine's inability to allow for "purposeful forward-looking agents." A second limitation arises as the differential equations embodied in the machine were linear and real world is likely much more complex. (pp.5-6).

On the question of forward-looking agents, incorporating expectations was to come later as described by Gordon (2008 and 2011). However, in a final unpublished note written when he had moved back to the University of Auckland, there is a suggestion that he foreshadowed the Lucas Critique[8] (Phillips 1972).

In contrast, he was clearly cognizant of the issue of non-linearity. In his 1950 paper documenting the details of the MONIAC, essentially a machine for solving differential equations, he wrote:

> "The hydraulic model will give solutions for non-linear systems as easily as for linear ones. It is not even necessary for the relationship to be in analytic form: so long as the curves can be drawn the machine will record the correct solutions, within the limits of its accuracy. In giving the equivalent mathematical model, however, the usual linearity assumption will be made, in view of the difficulty of working with non-linear differential or difference equations" (pp.287-288).

Furthermore, the inherent design of the machine was sufficiently flexible that it could adapted to such more recent institutional arrangements that did not exist at thte time; examples include floating exchange rates and monetary policy using interesdt rate targets.

An interesting historical aside is that in 1891, Irving Fisher presented a doctoral thesis which led to the award of the first PhD in economics at Yale University. In it he outlined the design of a "hydrostatic machine" which was subsequently built. In contrast to Phillips' subsequent work, Fisher had the causation running in the opposite direction; ie changes in the rate of inflation causing changes in the level of the unemployment rate.[9] The microfoundations of Fisher's model is flexible prices. This fundamental difference in the direction of causation underlies the view of

[8] The Lucas Critique argues that in predicting the effect of a policy change it cannot be assumed that the underlying structural relationships of an economic model would necessarily be invariant to the policy change itself.

[9] Kitov (2009) finds a statistically robust relation for a number of countries in which inflation leads unemployment as in Fisher, noting however that that does not establish causality.

Lucas where an unanticiapted change in say the money supply would be needed to generate a real effect on output and employment.

History does not record any mention in Phillips' writings of this earlier invention by Fisher.[10] In fact it is somewhat surprising that nowhere in the seven chapters dealing with the MONIAC machine in the edited volume of Phillips' collected works (Leeson (2000), Chs. 8-14), is there mention of the hydraulic model of Irving Fisher.[11]

Gordon (2008) recalls as Co-Editor he was responsible for reprinting Fisher (1926) in the *Journal of Political Economy* as Fisher (1973) and giving it the dramatic title, as he believed the Phillips Curve (so named by Samuelson and Solow, 1960) might better have become known as the Fisher Curve. So while the name "Phillips Curve" is so firmly grounded in the literature, it is pertinent to recall the Fisherian antecedents.

To what extent is the fundamental structure of the MONIAC machine mirrored in approaches to policy making? In 1997 the Reserve Bank of New Zealand based its forecasting and policy formulation on a model (Reserve Bank, 1997) whose key elements bear striking similarity to the those of the MONIAC machine (Figures 3 and 4). Both models are built around a common framework involving four broad sectors of the economy: households, firms, a government sector and a foreign sector. Household income is split between consumption and savings; firms invest in capital goods; the government generates revenue from taxes and adds to expenditure and the movement of goods and services between countries are captured by export and import flows. Of course, with the advent of electronic computerised modelling much great sophistication could be introduced than was possible with an analogue machine.

To what extent did Phillips' work on the MONIAC machine lead to his subsequent insights into stabilisation policy? We address that question in the following sections.

2.2 The Phillips Curve

While the well-known paper that gave rise to the naming of the Phillips Curve was published only in 1958, the origins go back to Phillips' earlier work. In Phillips (1954), a paper based on parts of his PhD thesis, he initially develops models of stabilisation under the assumption of constant prices and interest rates. He undoubtedly had similar ideas in mind when making the MONIAC machine some years earlier. He then extends these models to allow for flexible prices. In doing so he "postulates a relation between the level of production and the rate of change of factor prices" (p.307). He sketched this relationship; it is reproduced here as Figure 1 below. It is a relatively small step from here to the plot of the unemployment rate on the changes in factor prices (in this case wage rates) in Phillips (1958). It should be noted that Phillips' theoretical discussion on which Figure 1 is based, should go some way in dispelling the myth that the "curve" was merely an empirical observation as depicted in the 1958 paper.

In a paper addressing the relation between output and inflation Mankiw (2001) wrote:

[10] For further discussion of Fisher and Phillips see Leeson (1995). Fisher also used hydraulic analogies when analysisng the purchasing power of money (1911, Ch.VII).

[11] Although as noted by Dimand (2019) on p. 337 of Leeson (2000), Basil Yamey (2000) speculates that Phillips "would have been amused at finding Fisher and Tinbergen were among his supposed precursors".

> "The inflation-unemployment tradeoff is, at its heart, a statement about the effects of monetary policy. It is the claim that changes in monetary policy push these two variables in opposite directions. ...The inflation-unemployment tradeoff is not a statement 'that a scatter-plot of these two variables produces a downward-sloping Phillips curve' or 'that any particular regression fits the data well or produces any particular set of coefficients' (p.46).
>
> "The good news is that the inflation-unemployment tradeoff has a secure place in economics. … The bad news is that the dynamic relationship between inflation and unemployment remains a mystery" (p.59).

There have been a vast number of estimates made of the Phillips curve in many countries for different time periods. However as shown by Stock and Watson (1999 and 2008) and highlighted by Atkenson and Ohanian (2000), it has proved very difficult to find any model including the Phillips curve which could make inflation forecasts more accurately than a naïve model that simply uses inflation rates of the recent past as a predictor. Typically there has been a so-called flattening of the Phillips curve with the result that, in many instances, there has been little or no correlation between unemployment and changes in inflation. At the extreme end, some commentators have called for its total abandonment (eg Dorn, 2017).

This potential flattening is reflected in a speech by the former Governor of the Bank of England:

> "While the global Phillips Curve appears alive and well, globalisation has been accompanied by a weakening in the relationship between domestic slack and domestic inflation" (Carney, 2017, p.2).

A number of possible reasons have been offered (Ng, Wessel and Sheiner, 2018). These include globalisation allowing access to migratory labour to address very low unemployment and concomitant labour shortages. Reduced bargaining power may have lessened the ability of workers to negotiate higher wages when unemployment is low. And if firms and households believe that a central bank will maintain inflation near a target level in the medium term then their inflationary expectations may be well anchored.[12]

However, in more recent work however, Stock and Watson (2019) find that, when using improved measures of real activity and a new inflation index based on cyclical measures, they obtain strong correlations between the measure of cyclical activity and this index. In a similar vein, Lansing (2019) finds that by including an interaction term based on the multiplicative combination of lagged inflation and the lagged output gap, the forecasting accuracy of the Phillips curve can be improved, both within and out of sample.

Coibion *et al.* (2019) compile an extensive data set of time series for inflation expectaions for 18 countries and regions and analyse the pooled information. They find a strong relation between inflation and the unemployment gap, and conclude as follows:

> We document that an expectations-augmented Phillips curve can account for inflation not just in the United States but across a range of countries, once household or firm-level inflation expectations are used. (p.408).

McLeay and Tenreyro (2019) highlight a further reason why one might expect a flattening of the Phillips curve. Suppose the central bank pursues a policy of minimising the losses resulting

[12] For an analysis of the the anchoring of inflationary expectations see Jorgensen and Lansing (2019).

from deviations in both inflation and output from their respective target levels.[13] When output deviates below the target level, the policy response will be to increase inflation. This will induce a negative relation between inflation and the output gap "blurring the identification of the (positively sloped) Phillips curve" (p.1). For this reason, observed data will not necessarily identify the Phillips curve, and may help explain why many attempts at fitting the curve have been less than successful.

A further concern is highlighted by Hooper, Mishkin and Sufi (2019a and b) who argue that for decades the actual unemployment rates have differed typically by no more than one percentage point from the natural rate of unemployment. This lack of variability in the data has made it difficult to estimate a significant slope in the Phillips curve and added to the impression of flattening.

Jacob and van Florenstein Mulder (2019) examine the flattening of the Phillips curve in the case of New Zealand. They find that there has been a notable flattening and they ascribe this to increased volatility of supply side shocks, relative to those impacting the demand side.

What is the significance of this flattening for monetary policy? With a much flatter Phillips curve, and shocks arising on the demand side will have less effect on inflation. A monetary policy rule would then indicate that in order to dampen inflation, nominal interest rates would not need to be increased by as much as would have been the case with a steeper curve. As a consequence of this muted policy response, the demand shock will be more persistent potentially leading to greater volatility of the output gap.[14]

2.3 Expectations

> "What we know, or should know, from the past is that once inflation becomes anticipated and ingrained – as it eventually would – then the stimulating effects are lost." Paul Volcker (former Chairman of the Federal Reserve)

Phillips recognised a role for expectations from the very beginning. In the paper describing the hydraulic machine (1950) he notes that the simple model which determines the path of induced price changes could be further developed. This extension could in effect make the demand for liquid stocks a function of the rate of change in the price level "through a coefficient of expectations" (p.289).

In particular, Phillips (1954) envisaged that certain forms of price expectations could lead to destabilising outcomes. If changes in prices induce expectations of additional changes in the same direction, any deviation from trend in real output may be amplified. Should price expectations be such that any recent past changes will be reversed, then a proportional regulating mechanism would act to stabilise demand.

A formal statement of Phillips' concept of expectations resulted from a meeting with Milton Friedman at the LSE in May, 1952. At that time, at the University of Chicago, Phillip Cagan was working with Friedman on the demand for money but had not found "a workable representation of the expected change in prices" (Cagan, 2000, p.22).

[13] See Section 3 below for further discussion of this strategy.

[14] Iakova (2017) examines the case for the UK.

Phillips suggested to Friedman a way to formalise this by relating the expected change in prices to the difference between actual and expected changes. [15] On this basis Cagan developed a differential equation which he converted into a weighted average with geometrically declining weights attached to previous price changes. Cagan concluded that "Phillips deserves credit for what later came to be called 'adaptive expectations'" (p.22).[16] Cagan (1956) found that this model was empirically useful for money demand in the case of German hyperinflation.

The 1960s ushered in a large increase in computing power and with it the development of macroeconomic models. Typically, an adaptive expectations framework involving expected inflation based on set of lagged values was incorporated in these models (Gordon, 2008). It then became standard procedure for the equation of the Phillips Curve to include a term for inflation or wage rate expectations, resulting in the so-called expectations augmented Phillips Curve. The implication is that changes in actual inflation can shape expectations about the future course of inflationary changes.

A basic form of the Expectations-Augmented Phillips Curve (EAPC) is given by:

(1) $\pi_t = \pi^e + \alpha y' + v$

or inflation in the current period (π_t) depends on the expected inflation (π^e); a measure of economic activity, typically the size of the output gap (y') and a random shock term (v). It then remains to specify how the expectations are formed.

Equation (2) illustrates the most basic model in which the expected inflation rate for this year is equal to the expected rate for last year plus an error correction factor defined as the difference between the actual inflation and that which was expected; ie the forecast error made by economic agents when determining the previous rate of inflation.

(2) $\pi^e_{t+1} = \pi^e_t + \lambda (\pi_t - \pi^e_t)$

By repeated substitutions it can be shown that the expected inflation rate is the weighted average of past inflation rates with geometrically declining weights.

As Pitchford (2000) records, this was the approach used by Phillips in the unpublished paper (2000) he prepared on wage changes and unemployment in Australia while a Visiting Professor at the University of Melbourne in 1959. Pitchford concludes that lack of hourly earnings data may well have discouraged Phillips from pursing this further.

The 1970s saw three innovations to the basic Phillips curve in which wage rate inflation was inversely related to unemployment (Humphrey, 1985a). In summary these were:

- the original demand variable was defined as the difference between the actual and natural rate of unemployment;
- the incorporation of an expected inflation term; and
- the specification of a mechanism of how expectations of the future inflation rate were to be formed.

[15] For a comprehensive synopsis of Friedman's views on inflation and employment, stemming from an analysis of the Phillips Curve see Schwarzer (2018).

[16] See also Leeson (1994a). Again there is evidence that Fisher was a precursor of Phillips on the issue of adaptive expectations. See Fisher (1911).

In other words, the basic model was now modified in the manner shown by equations (1) and (2) above.

These innovations are associated with the work of Friedman (1968) and Phelps (1966 and 1967); the former associated with the importance of expectations and the latter with the natural rate of unemployment, although in fact both made contributions in both areas.[17] Their work, loosely called a "monetarist" view, highlighted the fact that only in the short-run could there be an unemployment-inflation trade-off, an interpretation of the original Phillips Curve that was dominant, especially in the USA in the 1960s. A monetary disturbance might result in a short run change in say unemployment, but once fully anticipated measures of real activity would return to what came to be called their "natural rate".

At each point in time, monetary policy needed to assess its impacts on inflation expectations, which underpin the shifts in the short-run Phillips curve. Aghion et al. (2008) conclude that this "intertemporal planning approach to monetary policy analysis is now at the heart of the approaches to policymaking now used by 'inflation-targeting' central banks in particular" (p.4). Clearly this outcome is direct result of building on the works of Phillips. To this end, Leeson (1977, p.166) suggested that the development of expectations should be known as the Phillips-Friedman-Phelps Critique, as Phillips had repeatedly noted the role of future price expectations (1950 and 1954).

The contributions of Friedman and Phelps represented an important step forward from the classical Phillips curve. It was now possible to reconcile the short run procyclicality of inflation and output (the supply side or Keynesian version of the Phillips curve) with the neutrality of monetary policy in the long run (the classical demand side, monetarist view).

A particular representation of the Phillips curve, referred to as the New Classical Phillips Curve is written as:

$$(3) \qquad \pi_t - \pi_{t-1} = \beta y_1 + [E_{t-1}(\pi_t) - \pi_{t-1}] + v_t$$

incorporating a term for the deviation of output from its natural rate (y_1) and an error correction term.

However, the adaptive expectations model implied that agents were backward looking. Moreover, it assumed that the weights attached to each of the historical observations were fixed and would not vary with changes in policy or the economic environment. As a consequence, under accelerating inflation, the adaptive expectations model implied those agents would consistently underestimate next period's inflation.

Lucas (1972 and 1973) argued this was unrealistic and proposed replacing the backward looking and slowly adjusting adaptive expectations model with an alternative model how expectations were formed. The concept of rational expectations had been introduced by Muth (1961). This formed the basis of the so-called Lucas critique, in which economic agents were assumed to base their expectations on all the available information, rather than solely relying on the history of past outcomes.[18]

[17] Birol (2017) provides a detailed analysis of Friedman's contribution and Aghion *et al.* (2008) reviews the contributions of Phelps. Lucas and Rapping (1969) address the role of expectations in the contecxt of the Phillips Curve.

[18] For an analysis of different types of inflation expectations see Hagemann (2020).

Lucas demonstrated that when a rational expectations framework was introduced in the neo-classical model with fully flexible prices, monetary policy would be impotent. No longer would agents be systematically fooled. Forecast errors could only arise from unanticipated random shocks. Only by creating a divergence between the actual and expected inflation could monetary policy have an impact in the short run on real output or employment.

Andrada (2017) uses citation data to analyse the influence of Lucas and papers that influenced him. Phillips (1958) features as one of the key papers in this latter category, but in the sense Lucas was focussed on the limitations of the Phillips curve. Furthermore, this is yet another case where, as Bollard (2016, p.140) notes, Phillips had presaged the Lucas Critique. In analysing the actions of government to address an excess demand for foreign currency, Phillips (1956) argues that impact of the policy intervention will depend on a series of responses by households and firms. Any assessment of the merits of alternative policies would require an understanding of the way those responses would change with different policies. In short, rational agents facing changes in economic policy may well alter their behaviour; this will result in a change in the behavioural relations within the structure of macroeconomic models.

An important issue for monetary policy is the matter of nominal rigidities. If all prices adjusted instantly and frictionessly, prices would simply become a numeraire. However, in reality this is not the case. As a result, changes in monetary policy can have impacts in the short run on real variables such as employment and output. Buckle and Meads (1991) explore the reaction of firms to unanticipated changes in demand, while Buckle and Carlson (2000) analyse the factors underlying price rigidity. Coleman and Silverstone (2007) offer evidence of price stickiness by documenting the frequency of price changes by New Zealand firms.

One approach to incorporating the effect of price rigidities follows Calvo (1983).[19] This led to the development of the so-called New Keynesian Phillips Curve (NKPC) by Roberts (1995).[20] Following Turnovsky (2008, p.25) it can be represented in its generic form as:

$$(4) \qquad \pi_t - \pi_{t-1} = \beta y_1 + \gamma[E_t(\pi_{t+1}) - \pi_t] \qquad \text{where} \quad 0 < \gamma < 1$$

which "differs from the New-Classical Phillips curve in that the expected inflation to which the current inflation is reacting extends for the next period (t, t+1) rather than the previous period (t-1, t)" (p.25). The NKPC has been widely used in dynamic, stochastic general equilibrium (DSGE) models such as that of Clarida, Galí and Gertler (1997, 1999 and 2000). The overriding lesson from the NKPC is that in the presence of price stickiness, a policy focus on inflation stabilisation is the optimal strategy.[21] Galí and Gertler (1998) conclude "that the New Keynesian Phillips Curve provides a good first order approximation to the dynamics of inflation".

However, as in many areas, further innovations occur. The McCallum (1998) critique of the NKPC based on sticky prices, is that it fails a fundamental test; namely that it violates the natural rate hypothesis. Permanently falling inflation in the NKPC would have a real effect, such that real output would remain permanently high. McCallum argued that, consistent with classical theory, it would seem improbable that the real wealth of an economy could be altered through paper money.

[19] For an extended discussion of a range of alternative formulations see Romer (2012), Ch.7.
[20] Hornstein (2008) provides a comprehensive introduction to the NKPC.
[21] Schmitt- Grohe and Uribe (2008).

Mankiw and Reis (2002) address this problem by introducing sticky information. In the Calvo model underpinning the NKPC, each firm has some probability of changing price in the current period. Mankiw and Reis introduce the notion of sticky information in which there is some probability that a firm will obtain information about the state of the economy. The consequence of this is a modified NKPC which the authors refer to as a Sticky Information Phillips Curve (SIPC). In the NKPC-Calvo sticky price model, the inflation rate is influenced by current expectations of future conditions. In the sticky information version, it is past expectations of current conditions that drive the inflation rate. As Cecchetti and Kim (2005) show, the nature of the expectations structure in the Phillips curve is a critical element in the debate of inflation versus price level targeting.

In a further elaboration of the Phillips curve, Gordon (1977, 1997, 2008 and 2013) develops a "triangle" model, in which the inflation rate depends on three basic determinants:

- Inertia: represented by the lagged rate of inflation ($\pi_{t\,j}$)
- Demand: or short-term Phillips curve inflation, represented by an index of excess demand (D) based on the output gap, or the unemployment gap or the rate of capacity utilisation
- Supply: represented by a series of supply side shock variables (Z) such as an oil price shock

Formally stated, the Triangle Model Phillips curve (TMPC) is given by:

$$\pi_t = \alpha(L)\pi_{t\,1} + \beta(L)D_t + \chi(L)Z_t + v_t \tag{5}$$

where L is the lagged operator and v a random error term. The inertia term and the supply shocks are shifters of the short-run Phillips curve and can change the trade-off. The TMPC differs from the NKPC in a number of ways. These are: the inclusion of longer lags on the demand variable (D); the explicit addition of supply shocks (Z) and long lags on the dependent variable (π_t). The inclusion of supply shocks then allows for the possibility of high inflation and contemporaneous high unemployment (the so called "stagflation" outcome).

When the demand variable is represented by deviations in the unemployment rate from the natural rate ($U_t - U_t^*$), the Triangle Model allows for a time-varying NAIRU (U_t^*). This is in contrast to the typical NKPC which uses a fixed value. Gordon (2008) estimates both a Triangle Model and a NKPC. For the particular data set and time period in the USA (1962 to 2007) he finds the TMPC outperforms the NKPC by a substantial margin, both in explaining past inflation and predicting future inflation for a 10 year out-of-sample period.

Of particular note is the finding that flattening of the Phillips curve, a typical outcome when estimating the NKPC, is strongly rejected by the TMPC. The slope coefficient in the NKPC is biased toward zero (implying flattening) due to the exclusion of supply shocks (Gordon, 2008, p.35 and Figure 6). This has clear implications for models of inflation forecasting and policy formation.

The findings of Gordon that there does not appear to be a flattening of the Phillips curve underscores the importance of both specifying the structure of the model to be estimated and the selection of the data as measures of the variables. These matters are further highlighted by the work of Hooper, Mishkin and Sufi (2019a) who demonstrate that the curve has a much more significant slope when data on inflation and unemployment for the USA are used at the more disaggregated level of Metropolitan Statistical Areas (MSAs) and states, rather than single national observations.

Eggertsson and Giannoni (2013) analyse the potential for a pronounced output-inflation trade-off in the context of current economic circumstances characterised by a zero lower bound. They demonstrate that the classical neutrality of monetary policy no longer holds if the short-term interest rate is constrained by a zero lower bound. Under these conditions, the anticipated inflation is far from neutral in the face of shocks. Output can increase if the anticipated inflation were to rise.

They conclude that under these circumstances, a case can be made for allowing the upper limit of the inflation target bound to increase temporarily. This would allow output and inflation to be better stabilised. However, a zero lower bound no longer applies, the conventional conclusion again holds; ie there is no real output gain to be had from invoking higher levels of anticipated inflation.

This section has stressed the ongoing importance of the Phillips curve and its variants. A summary of the intellectual ancestors and descendants of the Phillips curve is shown in Table 1.

3. Dynamic Stabilisation and Optimal Control

In 1954 Phillips published a paper entitled "Stabilisation Policy in a Closed Economy." This is arguably one of his most profound and pioneering pieces. He starts by noting that the method of comparative statics is unable to reveal the time path of income, production and employment following a policy intervention. Yet it may be that the path is unstable, may involve undesirable fluctuations and fail to reach a stable equilibrium. Furthermore Phillips argues that the simple multiplier models that typically underpinned comparative static analyses could not adequately handle changes in prices and interest rates. His paper addrssed these issues and was a major conceptual step forward at that time. It formed the springboard for subsequent work by Taylor.

If there is one single channel through which the work of Phillips lies at the heart of much policy evaluation today, it is as a result the work of John B. Taylor. His building on the work of Phillips started from the very beginning of his career at age 21 with an undergraduate thesis at Princeton, subsequently abridged and published as a Research Memorandum the same year by the Econometric Research Program at Princeton. The very first sentence of this, his first published work, cites Phillips (1954). He states the objective of his paper was to "briefly describe the product and money markets as developed by Phillips, and derive the government policies that will regulate the model" (1968, p.1). He further notes "the endogenous growth model that we shall use in this analysis is a modification of that developed by Phillips" (1961a, p.2).

In a series of papers, Taylor (1968, 1993, 1999 and 2017) developed and elaborated on an approach to monetary policy that became known as the Taylor Rule. It differed from earlier rules, in particular a monetarist rule, which was based on a steady and fixed growth rate of the money supply. Rather, it viewed the key policy instrument for counter-cyclical monetary policy as the short term nominal interest rate. This was seen as depending on the extent to which inflation and output deviated from there desired or structural levels. It is immediately apparent that this rule has strong antecedents in the Phillips Curve in which inflation was a function of either the level of some measure of economic activity (output or employment) or the deviation of that level from a benchmark (eg the natural rate of unemployment or the NAIRU. In fact, once monetary policy had moved on from its focus on the growth rate of the money supply, the Taylor rule became the primary operational framework for central banks (Asso and Leeson, 2012; Kohn, 2007).

The importance of the underlying Phillips Curve to the Taylor rule can be demonstrated with a basic three equation macroeconomic model. [22] The first two elements are as follows:

- *IS equation:* Real income is a function of autonomous spending and interest a lagged response to changes in real interest rates
- *Phillips Curve:* Inflation next period is determined by this period's inflation and a term reflecting the output gap

The central bank is concerned with both output fluctuations and deviations of the inflation rate from its target level. They aim to minimise a loss function which is made up of the squared deviations respectively of output and inflation from their target levels. The weights assigned to each of these terms will reflect the preferences of the central bank; in other words, the degree of aversion to deviations in inflation rates versus deviations in output. With this framework, a monetary rule for the simplest case involving equal unitary weightings can be derived as the third equation in the model:

- *Monetary Rule:* $(r_0 - r^*) = 0.5\ (\pi_0 - \pi^*)$

This tells the central bank the extent to which the interest rate needs to be adjusted relative to its target level in response to the deviation of the inflation rate relative to its target level. The target level for the interest rate (r*) is the "natural" rate or the rate consistent with stabilising output.

This result, in which the rule only reflects deviations in the inflation rate, was derived assuming a single policy lag between the interest rate change and real output. If an additional lagged response is introduced whereby next period's output (y_1) affects the inflation rate in the following period (π_2), a Taylor rule, incorporating deviations in both inflation and output can be derived. Again, for the case where the weights are both unitary, the following is the result:

- *Taylor Rule:* $(r_0 - r^*) = 0.5\ (\pi_0 - \pi^*) + 0.5\ (y_0 - y^*)$

This result states that in setting interest rates the central bank will be concerned with deviations of both inflation and output from their equilibrium or target levels.[23] The greater the response of interest rates to the output gap which in turn affects subsequent inflation, the less weight will be needed on deviations in inflation. Were the bank to attach zero weight to the output gap then greater weight would need to attach to the inflation rate.

In some versions, an unemployment gap may be used in place of the output gap. This is defined as an unemployment gap, $(u - u^*)$ where u* is measured by the NAIRU. However, as Rusticelli (2015) observes:

> "the apparent reduced sensitivity of inflation to labour market dynamics and unemployment gaps seriously undermines the use of Phillips curve equations in estimating the NAIRU" (p.109).

[22] This section draws on Walsh (2002) and Carlin and Soskice (2005). See also Poutineau, Sobczak and Vermandel (2015).

[23] Smith and Aziz (2019) analyse the twin objectives of monetary pocity in the context of New Zealand.

She finds that by modifying the way inflationary expectations are modelled, the estimate of the NAIRU is increased for a number of OECD countries with a consequent strengthening of the relationship between inflation and conditions in the labour market, and a concomitant steeping of the Phillips curve.

Clearly there are a large number of versions of the rule which can be derived. For example, where the bank considers the expected levels of future inflation and output, its response has to recognise that interest rate changes may affect inflationary expectations. However regardless of the embellishments one might want to incorporate, it remains that the Phillips curve is an integral part of the basic structure of a macroeconomic model and a key element in the derivation of the Taylor rule.[24]

Despite its widespread use, the Taylor Rule is not the only rule that a central bank might employ. Minford *et al.* (2003) find that a Taylor Rule and money supply rule produce significantly different outcomes, and argue that the money supply rule does not necessarily produce inferior welfare outcomes as implied by Clarida *et al.* (1999).

Walsh (1998) argues the case for relating the variability of inflation to the volatility of output. This is encapsulated in Figure 2 which has been called a Taylor curve. It follows from earlier work by Taylor (1979). Taylor had made the case that the short run inflation-output trade-off was consistent with a more permanent trade-off based on the variability of output and inflation. Based on this concept, the task of the central bank concerned with the output-inflation trade-off can be usefully broken down into two steps.

The first is to identify the efficient frontier. Its position will depend on the structure of the economic and the nature of economic innovations. This could result in a trade-off depicted by the dotted line. However, this would be inefficient as an alternative lies wholly inside the inefficient case, implying for any level of output volatility the inflation volatility is lower.

The second step is to select the preferred point on the efficient frontier. Here again it is the preferences of the bank, presumably reflecting those of society, that must be used to assign relative weights, as was the case for the Taylor rule. If the costs associated with inflation volatility are deemed greater than those associated with output variability then a position such as point A on the frontier may be preferred. Likewise, point B would be chosen when the costs of inflation volatility were deemed less than those arising from output variability. [25] Buckle (2019) analyses the use of the Taylor curve to assess the welfare implications of monetary policy decisions. He outlines how this is used by central banks and in particular its application in the RBNZ since the early 2000s.

Phillips started with a dynamic multiplier-accelerator model following Samuelson (1939) and Hicks (1950). Phillips paid particular attention to the matter of lags in the implementation of policy. The existence of lags is a key challenge facing stabilisation policy. His contributions in this area undoubtedly laid the foundations for the subsequent development of dynamic stabilisation modelling (Turnovsky, 1981 and 2008).

[24] For a detailed history of the Taylor Rule and its relation to the work of Phillips, see Asso, Khan and Leeson (2007) and Asso and Lesson (2012). Asso, Khan and Leeson (2010) review the Taylor Rule in the context of central banking.

[25] Chatterjee (2002) provides a clear discussion of the challenges in comparing the welfare implications of selecting different points on the Taylor curve.

Unlike previous work which had treated government expenditure as a given constant, a key innovation by Phillips was to endogenise government spending. By treating government expenditure as a policy variable, he allowed for continual adjustments to achieve specified objectives.

His papers on stabilisation policy (Phillips 1954 and 1957) drew out a number of key concepts and innovations that "can be regarded as a remarkable foreshadowing of many of today's macroeconomic models" (Pagan, 2000a, p.132). He emphasised the need for a dynamic framework (in contrast to the comparative static models of the IS-LM era), and paid particular attention to the importance of lags. He drew on his electrical background to introduce rules based on proportional, integral and derivative controls to achieve stabilisation. Pagan (pers.comm.) notes that integral control is basically a rule that involves a stock. This means, for example, that the use of rules aimed at achieving a particular ratio of debt: GDP (as in New Zealand) are essentially an example of integral control. In contrast, Taylor rules are proportional and derivative, depending on how they are set up. But Phillips also recognised the risk of interventions that might be destabilising. In a series of simulations, Spencer and Grimes (1980) found that the derivative based policy reaction was typically more effective in achieving stabilisation than other approaches.

4. Economic Growth

For much of his career, Phillips had concerned himself with the challenge of stabilising economic activity through the use of appropriate policy interventions. In particular, a central theme had been how to achieve a level of unemployment without risking accelerating inflation. His work had, to this point, not specifically addressed the issue of long run economic growth.

However, Phillips was well aware of the both the growing literature on, and modelling of growth; furthermore, it was apparent that some countries were doing much better than others in achieving both a stable and growing economy. He set himself the challenge of developing a model that would address "both the problem of reducing short-period fluctuations of an economy and the problem of attaining longer-term objectives relating to employment, the price level and growth" (1961a, p.360).

A central element was the concept of 'normal capacity output'. This was the critical piece that allowed Phillips to address both stabilisation and growth. The difference between the actual output and the normal capacity output constituted what became to be called an output gap which is integral in the Taylor rule. The rate of inflation was then driven by the magnitude of the gap. Normal capacity output would grow over time as a consequence of investments made to improve the productivity of resources.[26]

The resulting model generated steady or equilibrium growth paths. In addition, short-term deviations from those paths provided a means to explore both the stability of the system, and at the same time analyse the effectiveness of stabilisation policies. While the stability of the model could be explored using different assumed values for the key parameters, Phillips concluded that for practical application of models of this type to actual policy making, there would be a need for "extensive work on empirical estimation" (p.369). In fact, Phillips himself did pioneering work on methods of estimation, and his modelling of stabilisation and growth laid the foundations for further developments.

[26] A non technical presentation of the key themes of employment, inflation and growth was given in Phillips' inaugural lecture for the Tooke Professorship at LSE (1961b).

Phillips (1961b) addressed the question of whether any increase in unemployment associated with policies to control inflation might be prejudicial to overall economic growth. He argued this was unlikely and stressed that economic growth depended on the willingness to save, and enhanced productivity through such factors as education and research. Incidentally, his reference here and elsewhere to the role of human capital predated the Beckerian revolution.

Laidler (2001) refers to working with "one of his [AWHP] most able and intellectual grandchildren, Peter Jonson, in the 1970s" (p.2). Peter Jonson joined the Reserve Bank of Australia some time in the early mid-seventies and has authored a huge volume of research papers. Laidler goes on to note Jonson was instrumental in introducing the Bergstrom-Wymer model to the RBA (fn.7). Fahrer *et al*. (1984) cite Challen and Hagger (1979), who referred to the Bank's model RBII as belonging to the Phillips-Bergstrom-Wymer class of models.

Bergstrom (2000b) himself points out that this model was "descended from the cyclical growth model developed in another of Phillip's pioneering contributions." That contribution was the development of "dynamic disequilibrium models which synthesise real and monetary phenomena, and cycles and growth as did Phillips' model" Bergstrom (2000a, p.192). The model of Phillips to which Bergstrom refers is Phillips (1961a).

5. Econometrics

Despite Phillips' substantial theoretical insights, he remained conscious of the needs to populate the models with empirical estimates of the key parameters. Only in this way could the models make a real contribution to the formation and implementation of economic policy. The following quotes encapsulate the importance Phillips attached to empirical estimation.

> "In dealing with questions of economic policy it is necessary to form some judgement about the magnitudes and time-forms of the responses of individuals or groups of individuals to changes in certain of the conditions confronting them" (Phillips, 1956, p.99).
>
> "It is clear that some quantitative knowledge about the responses in the system is necessary both for rational discussion of the relative merits of alternative policies and for the satisfactory implementation of whatever policy is adopted" (Phillips, 1956, p.100).

From the end of the 1950s and throughout the 1960s Phillips concentrated his efforts on developing econometric techniques that would contribute to the estimation of theoretical economic models.

The development of continuous time dynamic models ran up against a computational challenge. Solving systems of simultaneous equations in discrete time was challenging enough on a Marchant electro-mechanical calculating machine.[27] But estimating a model of non-linear simultaneous equations in continuous time was simply not feasible. To that point most econometric work had been built on discrete time data (quarterly or annual observations). Phillips was able to demonstrate the use of discrete time data in order to restrict a continuous time model.

As Peter Phillips (2000) notes: "one of Phillips' greatest contributions to econometrics is that he opened up a new field of research on continuous time econometric modelling and statistical

[27] This machine was still very much in use when I started my research career in Canberra. In 1963 I estimated multiple regressions based on the reverse Doolittle method using this machine – to say it was a slow, painful process, susceptible to error would be a gross understatement.

inference" (p.342). The development of dynamic models as systems of differential equations provided the foundation for explaining cyclical deviations in economic performance. Critically they provided way to explore alternative control mechanisms designed to stabilise the system.

To a large extent subsequent advances in statistical techniques and dramatic gains in computing power have meant that modern macroeconomic modelling does not directly incorporate the work of Phillips. What is undeniable however that his pioneering work on dynamic macroeconomic models, error correction mechanisms, control methods and the estimation of continuous time systems underpins much of the econometrics involved in today's design, estimation, forecasting and policy formation using macroeconomic models.[28]

6. Forecasting and Policy Models

There is a wide array of macroeconomic models used for forecasting and as the basis for developing policy responses. Typically, a monetary authority uses some form of a dynamic model. And almost all contain elements of Phillips' legacy, either directly or indirectly. Frequently, a suite of models is employed to address a range of issues including checks on the robustness of the forecasts (Hara, 2009; Cusbert and Kendall, 2018).

Many of these models allow for the gradual adjustment of economic measures (eg output or employment) to some target value, a framework almost mirroring the approach of Phillips. Incomplete information, transactions costs and uncertainty all govern the speed at which the models approach the equilibrium values of the target variables. In the long term the solutions are in accord with the neoclassical premises (Jonson and Wymer, 2017).

A useful guide to macro models is given by Pagan (2003). Figure 5, taken from Pagan (p.68), plots a trade-off faced by macro-mpdellors between the degree of theoretical coherence against the degree of empirical coherence.

> At one end of the curve are theoretical models that have never been exposed to an historical data set, while, at the other, there are models that fit every quirk in the data set but whose outcomes are impossible to interpret. Being at either of these points is not particularly attractive to a policy-maker and so models used in the policy process have always been located along the interior points on the curve. Of the categories of models listed previously, DSGE models tend to be closer to the left-hand end of the curve, while the early macro models were close to the right-hand end. Over time the curve has shifted outward and it has been possible to attain the same degree of empirical coherence with stronger theoretical constructs (Pagan, 2003, p.68).

Early time series models were largely at the empirical end of the curve, in contrast to models with a strong theoretical foundation. Most central banks today use hybrid models combining theory and data matching.

This section first considers the models used in New Zealand (Section 6.1). This is followed by a brief sketch of the approaches used in a sample of other countries.[29] In each case links are

[28] For extensive discussions of Phillips' econometric legacy see P.C.B.Phillips (2000), Hendry and Mizon (2000), Bergstrom (2000b), Hansen and Sargent (2000) and Pagan (2000b).

[29] A number of versions of the MONIAC machine were built and sold to various agencies, largely universities. It appears that with the exception of one purchased by the Ford Motor Company, the only example acquired by a Central Bank was that sold to the Bank of Guatemala. In March of 1953, the US economist Abba Lerner who had

drawn to the work of Phillips. There is no pretence that what follows is in any way a comprehensive view of the selected cases. The reader wishing more detail is referred to the sources.[30] The objective is simply to highlight very briefly those areas where the intellectual footprint of Phillips is evident. This will inevitably mean a focus on the Phillips curve and its descendants including the Taylor rule. In no way should this be taken as overlooking the other wide ranging contributions of Phillips. It is simply these are diffused through the DNA of the models, their econometric estimation and application. The previous sections of the essay have endeavoured to identify and trace those "indirect" contributions.

6.1 New Zealand:

Black *et al*. (1997); Ng and Wright (2007); Delbrück (2008); Kamber *et al.* (2016) Benes *et al.* (2009).

Since 1990, monetary policy in New Zealand has been based on an inflation targeting approach very much in the spirit of Phillips' approach to policy rules (Buckle, 2018 and Grimes 2104). Starting in the mid 1990s the Reserve Bank developed a macroeconomic model for New Zealand known as the Forecasting and Policy System (FPS). It remained in use for more than a decade and was upgraded a number of times.

Inflation in FPS was driven by excess demand and inflation expectations via a calibrated Phillips curve relationship, where excess demand is measured by the output gap (the difference between actual and potential output), and inflation expectations are determined by a mixture of backward and forward looking expectations. FPS used an endogenous interest rate, and solved for the path of the short-term interest rate that would meet the inflation target over the medium term, while avoiding unnecessary instability in other variables.

In contrast to the use of an output gaps for driving inflation, a model known as the *Kiwi Inflation Targetting Technology* (K.I.T.T) employed the pricing decisions of firms that are subject to nominal rigidities. The monetary authority sets policy according to a variant of the Taylor rule.

The Reserve Bank of New Zealand currently utilises an economic forecasting and policy analysis model of the DSGE family, known as NZSIM. The model employs three Phillips curves to describe price formation: these are for domestic prices, exports and imports. In each case, an adaptive expectations framework is used. The Bank sets the nominal interest rate using a generalised Taylor rule. This has as its arguments:

- a lagged interest rate with a parameter that governs the degree of interest rate smoothing;
- the deviation of the expected inflation in the next period from its steady state level;
- an output gap which is derived from the model, and defined as the difference between actual output and the level of output that would prevail in the absence of nominal rigidities.

There is a very wide range of papers relating to the Phillips curve which have been published by the staff of the Reserve Bank of New Zealand. These can be accessed with the following link: https://www.rbnz.govt.nz/search?q=The+Phillips+curve

6.2 England:

Bank of England (2004); Harrison, *et al.* (2005); Castle and Hendry (2007); Pagan (2003 and 2005); Arestis and Sawyer (2002).

assumed the role as the North American agent, travelled to Guatemala to help set up the machine and provide instuctions in its use. The extent to which it was used in formulating economic policy is not recorded. See Stevenson (nd).

[30] While every effort has been made to document the latest versions of the models currently in use, it is recognised that these are constantly being updated as innovations are incorporated.

The Bank of England uses a Quarterly Model (BEQM) which is an advanced version although similar to the earlier Medium-Term Macro Model (MTMM). The nominal side of the economy is anchored by a Taylor rule; the Bank adjusts the interest rate in which the short-term(one-period) nominal interest rate is used to ensure that annual CPI inflation is ultimately maintained at a target level of 2%.

6.3 Australia:

Cusbert and Kendall (2018); Gruen, Robinson and Stone (2002); Pagan (2019); Pagan and Wilcox (2016); Ballantyne, et al. (2019).

The Reserve Bank of Australia uses a suite of models including MARTIN, a full system error correction model. It complements a DSGE, a VAR and others for forecasting and policy analysis. The RBA has made extensive use of variants of Phillips curves.

Ballantyne *et al.* note that…

> "We model the WPI (wage price index) using a Phillips curve approach. Less spare capacity in the labour market, as measured by a decreasing unemployment rate and smaller unemployment gap, will lead to faster wages growth. Higher inflation expectations and faster growth in the GDP deflator also raise wages growth, as nominal wages will need to increase more quickly to maintain a given real wage. An increase in productivity growth also leads to faster wage growth, because it raises the marginal product of labour" (2019, p.25).

6.4 Canada:

Gervais and Gosselin (2014); Dorich *et al.* (2013); Laidler (2015): Ambler (2009).

For macroeconomic forecasting the Bank of Canada. uses a large-scale Canadian model called LENS (Large Empirical and Semi-structural model). This is complemented by ToTEM (Terms-of-Trade Economic Model), or which has served as the Bank's main projection and policy analysis model since December 2005. It has been updated to ToTEM II. Both models involve a Phillips curve.

In an analysis of inflation targeting in Canada, Laidler (2015) notes that monetary policy is founded on a DSGE "standard" model. A key element is expectations-augmented Phillips Curve (EAPC) where deviations from expected inflation are driven by the output gap.

The Bank of Canada conducts its monetary policy based on inflation targeting. It has however been reviewing the case for price level targeting (Ambler, 2009).

6.5 Germany:

Deutsche Bundesbank (2008).

The Bundesbank uses a series of DSGE models. These models are modified to reflect the significance of Germany in the EU and the role of the monetary union. The following extract summarises the inflation and monetary policy elements of the basic model, and reflects the legacy of Phillips.

"Inflation dynamics.

Aggregate inflation dynamics derive from firms' price-setting behaviour. The inflation rate is given by a Phillips curve

$\pi_t = \beta E_t(\pi_{t+1}) + \kappa\varphi_t + \varepsilon_{\pi t}$

The parameter κ gives the elasticity of inflation to marginal costs. Inflation can also be driven by a cost-induced inflation shock $\varepsilon\pi t$.

Monetary and fiscal policy.

Monetary policy is described by an interest rate rule:

$i_t = \rho i_{t-1} + (1 - \rho)(\varphi_\pi \pi_t + \varphi_x x_t) + \varepsilon_{it}$

This implies that the central bank wants to stabilise inflation and deviations from long-term potential output x_t without causing interest rates to fluctuate excessively. Parameter ρ describes the degree of interest rate variation. If the economy overheats, leading to $\pi_t > 0$ and $x_t > 0$, the central bank will raise the nominal interest rate. The extent to which the interest rate increases is dependent on the interest rate response coefficients of inflation $\varphi_\pi > 1$ and of the output gap $\varphi_x > 0$" (p.36).

6.6 USA:

Brayton, Laubach, Reifschneider (2014); King (2008); Barkbu *et al.* (2005).

Ben Bernanke (2007), as Chairman of the Federal Reserve System, when underlining the growing importance of models, stated:

> "Indeed, considerable progress has been made in recent years, at the Board and elsewhere, in developing dynamic stochastic general equilibrium (DSGE) models detailed enough for policy application. These models have become increasingly useful for policy analysis for the simulation of alternative scenarios. They are likely to play a more significant role in the forecasting process over time as well, though, like other formal methods, they are unlikely to displace expert judgement" (Bernanke, 2007).

Donald Kohn, former Vice Chairman of the Board of Governors of the Federal Reserve System made very clear the role Phillips in underpinning modern policy making.

> "A model in the Phillips curve tradition remains at the core of how most academic researchers and policymakers--including this one--think about fluctuations in inflation; indeed, alternative frameworks seem to lack solid economic foundations and empirical support" (Kohn, 2008).

The central model used by the Federal Reserve Board is the FRB/US model. While have many elements in common with a DSGE model, it differs in relying less on economic theory. For example, unlike a DSGE model the household sector is not based on a utility maximising representative household. This allows greater flexibility, and allows the macroeconomic data to influence the structure of the model.

The key inflation measures modelled in FRB/US are for core PCE prices and ECI hourly compensation, following the New Keynesian Phillips curve specification in the presence of nonzero trend inflation. In addition to slack and expectations of future inflation, other important determinants of total consumer price inflation include movements in the relative prices of food, energy, and non-energy imports.

King (2008) provides a detailed review of the evolution of the Phillips curve in macroeconomic policy analysis in the United States. Toward the end of the historical period examined here (1958-1996), the Federal Reserve System had decided to maintain a goal of a low, but positive rate of inflation. The decision to choose a positive rate of inflation was traced, in part, to a concern about the transitory unemployment costs of moving to a zero rate of inflation and in part to a concern about high long-run costs of low inflation, in the spirit of Phillips' analysis.

6.7 Japan:

Hirakata *et al.* (2019); Hara *et al.* (2009).

The Bank of Japan uses a large-scale semi-structural model of the Japanese economy known as Q-JEM. The model differs from a DSGE type model and is similar to that used in Australia (MARTIN), Canada (LENS) and the USA (FRB/US). While lacking the theoretical microeconomic foundations of a DSGE, these models allow greater flexibility.

In Q-JEM, core inflation, is determined by the Phillips Curve which has as its arguments a long term inflation expectations (6 to 10 years ahead) derived from an inflation survey; an output gap, and one and two period lagged inflation rates.

A satellite model, the Trend Inflation Projection System (TIPS) is used to develop long-term inflation expectations which obey a process similar to Phillips Curve. The central bank operates monetary policy by setting the policy rate according to a Taylor rule with interest rate smoothing.

6.8 European Central Bank:

Eser (2020); Ball and Mazumder (2020); Arestis and Sawyer (2002).

The European Central Bank (ECB) uses a structural Phillips Curve, which is embedded in the semi-structural models used at the ECB. The structural Phillips Curve specifies that deviations of inflation from its steady-state level are a function of: (i) the degree of slack in the economy; (ii) inflation expectations; and (iii) shocks to the mark-up over marginal cost in the prices set by firms.

The actual structural Phillips Curve is represented by the New Keynesian Phillips Curve which forms the backbone of the structural framework that underlies the family of DSGE models used regularly at the ECB. The cornerstone of actual policy making at the ECB is a Taylor-type interest rate feedback rule.

> " All in all, we consider the Phillips Curve framework to be a helpful way to understand the transmission of ECB monetary policy in recent years" (Eser et al. 2020, p.3).
>
> "We find that fluctuations in weighted median inflation in the Euro area are well explained by a simple Phillips curve. In this equation, median inflation is determined by expected inflation, the gap between actual and potential output, and the pass-through of headline-inflation shocks to core inflation" (Ball and Mazumder 2020, p.15).

6.9 Chile:

Garcia *et al.* (2019).

The Central Bank of Chile uses a DGSE model known as XMAS: Extended Model for Analysis and Simulations. It is used for macroeconomic projections and monetary policy analysis. Given its importance the mining sector, representing 10% of GDP, is treated endogenously. The model uses Calvo pricing and its monetary policy is based on the Taylor rule.

6.10 France:

Lemoine *et al.* (2019).

The central macroeconomic model used by the Banque de France (FR-BDF) is a new semi-structural replacement of the older model, Mascotte.

"FR-BDF is a large-scale model for France, which contains detailed behavioural equations as well as a detailed accounting framework. It is used both for medium-run projection exercises and for policy analysis. The French economy is modelled as a small-open economy under fixed exchange rates with an exogenous interest rate due to the constraints of the Eurosystem projection framework" (Lemoine et al. 2019, p.ii).

A small structural VAR model is used as an expectations satellite (E-SAT) with two blocks: one for France and a second for the euro area. In each block there is an IS and Phillips curve. The bocks are completed with a Taylor rule which sets the interest rate, the arguments being the interest rate, its lagged value, euro area inflation, and the euro area output gap.

6.11 Turkey:

Büyükbaşaran, Çebi and Küçük (2018).

The Central Bank of Turkey has developed a small-scale open economy New Keynesian Dynamic Stochastic General Equilibrium (DSGE) model. It incorporates a log-linearized hybrid Phillips curve in terms of deviations from steady state. Inflation is driven by future expected inflation and past inflation reflecting inflation inertia. In particular the Phillips curve includes a term for the real marginal cost of output.

> "Government spending and income tax as well as output gap directly affect real marginal cost and hence they indirectly affect inflation. In this model, tax is a cost element for a firm. An increase in income tax rate directly increases real wages which also affects firm's real marginal cost. Therefore, an increase in real marginal cost is reflected in the price of a product and also in inflation. The slope coefficient of Phillips curve shows the sensitivity of domestic inflation with respect to real marginal cost" (Büyükbaşaran, Çebi and Küçük, 2018, p.4).

7. Conclusions

William Baumol described Phillips as "one of the most remarkable economists of the twentieth century, indeed of all time… and had he lived longer might well have won a Nobel Prize." [31]Arguably many of the developments in macroeconomics since the 1960s, whether it be stabilisation, economic growth, monetary policy, the control of inflation or the econometrics needed to quantify and apply theoretical models, have their origins in, or have been influenced by the work of Phillips. Few economists of that era could claim a legacy as extensive or profound as that of Alban William (Bill) Housego Phillips.

[31] Cited in Leeson (1994b).

There is however a certain irony in that legacy. Without doubt Phillips' 1958 paper on wage rates and unemployment (subsequently named the Phillips Curve) is the most widely known of his work. Yet he himself never regarded it as particularly significant, and there is no evidence he promoted it as a model for policy making. There is nevertheless, a substantial body of modelling which builds on the descendants of the Phillips Curve.

In his paper on the Australian economy written in 1967, Phillips (2000) stated:

> "One of the main economic problems in Western countries today is whether it is possible to prevent continually rising prices while maintain high levels of economic activity" (p.269).

Nothing could be closer to the primary tasks of many a central bank in the formulation of monetary policy today. This is encapsulated in the Charter of the Monetary Policy Committee of the Reserve Bank of New Zealand which states:

> "The Monetary Policy Committee (MPC) is responsible for formulating monetary policy directed at achieving the economic objectives of price stability and support of maximum sustainable employment."[32]

Much of Phillips' work and its many descendants addressed precisely the challenge implied by the objectives of the MPC; namely can a modern economy simultaneously achieve sustainable employment and price stability? This alone provides prima facie evidence that Phillips' contributions continue to be relevant to economic policy making some seven decades after he first described the MONIAC machine (1950).

Phillips constantly sought to use theoretical models to derive implications for practical policy making. His insights on policy options remain as vivid and relevant today as they were some 60 years ago. In relation to fiscal policy, he felt the lags in developing and applying public expenditure were too great for that to be an effective stabilisation tool, and favoured the use of taxes (and by implication automatic stabilisers) to achieve short term management of aggregate demand. In contrast monetary policy should be directed to achieving longer term price stability and the availability of credit. He saw monetary policy having but a modest role in the management of short run fluctuations.

While not prolific in terms of publications, a case can be made that his real legacy derives from an important and far reaching set of contributions that go well beyond the inflation-output debate. This essay has attempted to highlight those contributions in the broad areas of stabilisation and optimal control, growth and econometrics. Phillips' work in these areas was driven by an underlying "profound sense of the potential social importance of macro-stabilisation policy" (Laidler, 2011, p.3).

Another significant element of his legacy surely lies in the cadre of students he taught, and colleagues with whom he worked. Any such listing would include some the most outstanding and well known economists and econometricians of recent decades. Of these a seemingly disproportionate number were Australasians including Peter Whittle, Peter C. B. Phillips, Cliff Wymer, Rex Bergstrom, and Adrian Pagan to name just some.

[32] See: https://www.rbnz.govt.nz/monetary-policy

Coda

If Bill Phillips were Governor[33] ... he would have met with the Minister last week and signed the Policy Targets Agreement with which he wholeheartedly endorsed. On the first day in office he would listen to his advisors from the senior management team who would lay out the challenges facing the Central Bank in formulating monetary policy at that moment. He would be appraised of the current performance of the economy as captured in the main indicators and their trends. He would learn of the current institutional arrangements for monetary policy. And he would ask about current fiscal policy.

On the second day he would refresh his memory and reread a selection of the key papers he wrote 60 or more years ago. In addition, he would review the subsequent contributions by his intellectual grandchildren who had built their work on a Phillipsian foundation. On the third day he would use the frameworks and models set out in those papers and their descendants to determine a way forward. In particular he would have been concerned with threats to financial stability arising from the many shocks to the global economy (GFC, Covid-19) and the implications of climate change. Before lunch, his Executive Assistant reminded him he had a meeting of the Monetary Policy Committee, later that day. He would (with his customary humility) make a suggestion to the Committee.

In short, the MPC, with its usual rigour, vigoursly debated his proposal; but finally had no hesitation in accepting and endorsing his policy recommendations, recognising the solid foundations on which the Governor was drawing.

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[33] From all we know of his life and work, it is highly unlikely he would have had any interest in the position!

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Table 1: The Phillips Curve (PC): A Genealogical Sketch

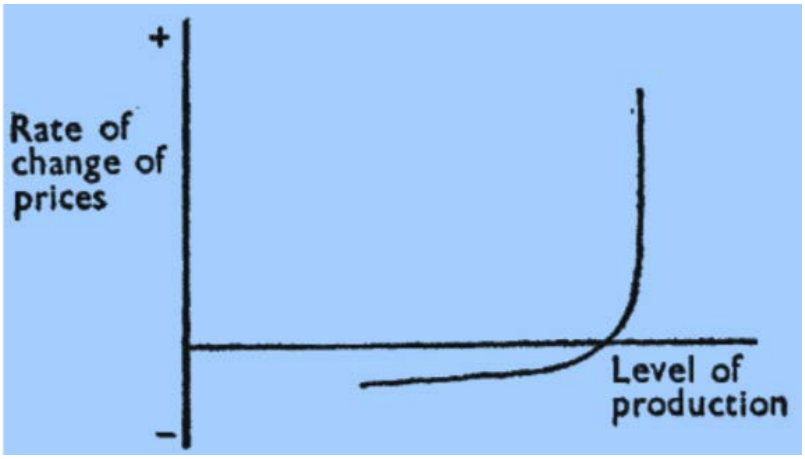
Author	Date	Key features
Ancestors[(1)]		
J. Law	1671-1729	An implied positively sloped PC where a reduction in umeployment is associated with an decrease (not an Increase) in prices.
D. Hume	1711-1776	A deviation of unemployment from its natural rate was driven by a change in the price level at least in the short run. Classical neutrality held in the long run once perceptions catch up. …"it is no matter of consequence to the domestic happiness of a state whether money be in greater or lesser quantity."
H.Thornton	1760-1815	As in Hume, he posited a relation between "industry" and prices, noting however that is the changes not the levels that mattered. He saw that a one off increase in the money stock would not after a lag stimulate output; rather a "progressive augmentation" would be needed.
T. Attwod	1783-1856	Based the case for an inflation-unemployment ratdeoff where both were in levels not changes. As low unemployment was associated with a high price level he concluded governments should aim for zero unemployment through inflationary monetary expansion.
J.S. Mill	1806-1873	In contrast to Attwood, Mill argued trade-offs were tempoarary and the government could not achive a particular level of unemployment by selection and inflation rate as in the steady state the two variables are independent (ie a vertical PC)
I. Fisher	1926	Analysed the relation between unemployment and lagged changes in prices. Claimed it was a causal relation running from price changes to unemployment (ie the reverse ditection to that of Phillips).
J. Tinbergen	1936	First formal econometric estimation of changes in the wage inflation rate as a function of unemployment.
L.Klein and A. Goldberger	1955	Further econometric estimation of the Phillips curve in which the dependent variable was a change in wage rates and the explanatory variables were total unemployment and the lagged change in the price level. In effect this a wage reaction function where changes in nominal wages reflect excess demand in the labour market.
A.J. Brown	1955	Conducted an empirical analysis plotting long run series of wage inflation against unemployment rates for the USA and the UK. Concluded there asn inverse, non-linear relation.
P. Sultan	1957	Plotted a stable hypothetical relation between the annual percentage change in the price level and the percentage unemployment rate.
A.W.H. Phillips: The Phillips Curve (1958)		
Descendants [(2)]		
E.S. Phelps M. Friedman	1967 1968	*Expectacions Augmented Phillips Curve (EAPC)* Highlighted the role of expectations and long run classical neutrality vertical PC (the monetarist approach) Expectations were based on backward looking model of lagged previous price or wage changes (adaptive expectations)
R.E.Lucas	1972 1973	*New Classical Phillips Curve (NCPC)* The Lucas critique focussed on the formation of expecatations. Rational expectations are forward looking and economic agents use all relevant information. Current inflation depends on the previous period's expectation of current inflation together with an output or employment gap; ie deviation from the natural rate of unemployment (NAIRU) was included. However the extended version still supported and strengethened the monetarist approach . In the long run the PC is vertical output and employment are unchanged by inflation.
G. Calvo J.M.Roberts	1983 1995	*New Keynesian Phillips Curve (NKPC)* Departed from Real Business Cycle (RBC) models by introducing sticky prices, which in turn allowed short run inflation-output tradeoffs while preserving long run classical neutrality. Current inflation depends directly on expected future inflation as well as the output gap.
J.B. Taylor	1993	*Taylor Rule* A rule for setting monetary policy whose derivation follows from the Phillips curve. It involves the weigted sum of deviations of both inflation and output from their equilibrium values.
N.G. Mankiw and R.Reis	2002	*Sticky Information Phillips Curve (SIPC)* Assumes firms not all receive the relevant information for setting prices at the same time.
R.J. Gordon	2008	*Triangle Model Phillips Curve (TMPC)* Current inflation depends on three variables (each with lags): inflation, demand side variables and supply shocks. In addition allows for the NAIRU to vary over time rather than being setting as an exogenous constant in earlier models.

Notes:

(1) Information on the ancestors is taken from Humphrey (1985b).

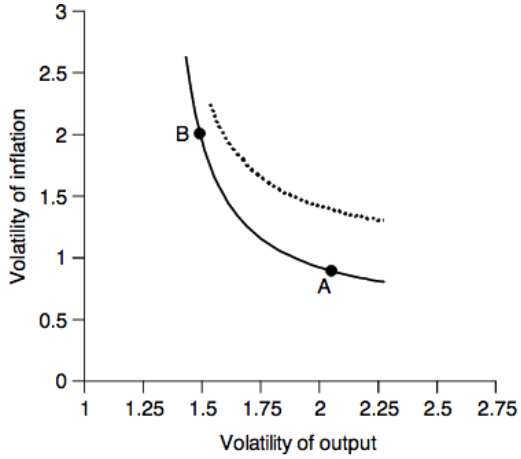
(2) In some cases the author listed is selected merely as one possible example.

Figure 1: A precursor of the Phillips Curve



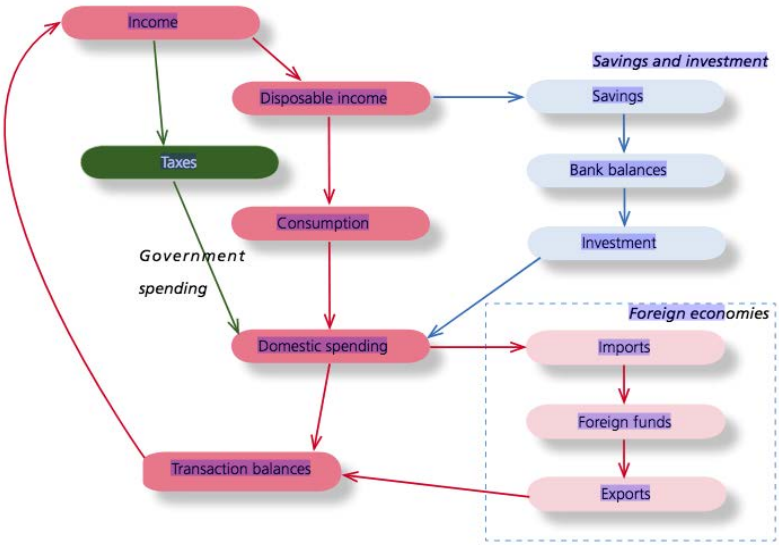
Source: Phillips (1954, p.308)

Figure 2: The output-inflation volatility trade-off



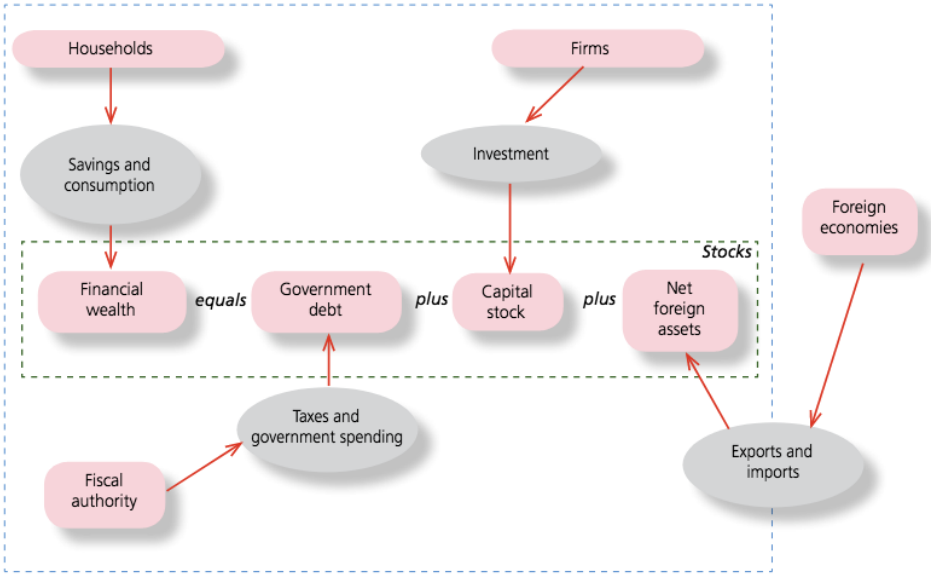
Source: Walsh (1998)

Figure 3: A simplified flow diagram of the MONIAC



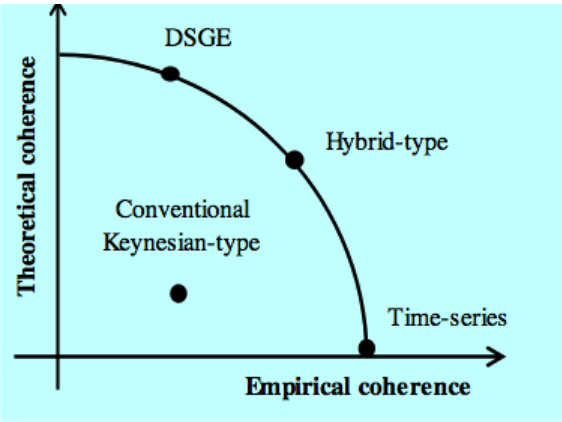
Source: Ng and Wright (2007)

Figure 4: Stocks and flows as represented in the Forecasting and Policy System



Source: Ng and Wright (2007)

Figure 5: A suite of models



Source: Pagan (2003)

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